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Chapter Twenty-eight

GENERAL INFORMATION

In aggregate, Part IV discusses INDOT policies, practices and procedures for performing hydraulic analyses on those projects which are the responsibility of the Department. Specifically, Chapter Twenty-eight discusses general information on INDOT hydraulic practices. This includes defining the responsibilities of Department units in hydraulic analyses, discussing the coordination between the *Indiana Design Manual* and the AASHTO *Model Drainage Manual*, describing the basic legal authority for drainage, presenting the documentation requirements for the hydraulic analyses, and discussing the Department's Pipe Classification System.

28-1.0 GENERAL

28-1.01 Introduction

For highway applications, hydraulics is the science of collecting, transporting and disposing of surface water originating on or near the highway right-of-way or flowing in the streams crossing or bordering that right-of-way. Proper drainage control is one of the essential elements of highway construction, and the cost for the adequate removal of surface water justifies a careful and scientific approach for the design of drainage facilities. A large percent of highway construction costs is devoted to culverts, bridges and other drainage structures.

Drainage design is a unique field of Civil Engineering because there are no definitive methods or rules that provide absolute answers to engineering questions. The hydraulics designer must rely on engineering judgment, experience and common sense to achieve meaningful results. The many drainage design methodologies available to the designer are only tools to aid the engineer in making judgements. The drainage designer must fully understand each method that is employed, especially their limitations. Only with understanding can the designer be assured of producing a reasonable hydraulics design.

For the *Indiana Design Manual*, highway drainage design will be confined to methods of preventing the accumulation and retention of water on and by the roadway through:

1. anticipating the amount and frequency of storm runoff;

2. determining natural points of concentration and discharge and other hydraulic controls;

3. providing the most efficient disposal facilities consistent with cost, the importance of the road, maintenance and legal obligations; and

4. removing detrimental amounts of subsurface water.

In hydraulic design, the basic objective is to protect the highway against damage from storm and subsurface waters considering the effect of the proposed improvement on traffic and property. Therefore, unless the State will benefit, no improvement in the drainage of areas outside the right-of-way is warranted.

28-1.02 Responsibilities

28-1.02(01) Department-Designed Projects

For those projects designed in-house by INDOT personnel, the following summarizes the responsibilities of Department units:

1. Designer. For roadway drainage appurtenances, the designer is typically responsible for the hydrologic/hydraulic analyses for the following:

   a. open channels, and
   b. pavement surface drainage,

   An exception to the above is for urban areas where the drainage basin exceeds 80 hectares. In these cases, the Hydraulics Unit is responsible for the analysis.

   In addition, the designer is responsible for gathering all needed information for the hydraulic analysis of culverts and storm drains.

2. Hydraulics Unit. The Hydraulics Unit is typically responsible for the hydrologic/hydraulic analyses for the following:

   a. bridge waterway openings (in coordination with the designer),
   b. all culverts,
   c. all urban areas where the drainage basin exceeds 80 hectares,
   d. closed drainage systems, and
   e. as requested by the designer.

In addition, the Hydraulics Unit is responsible for developing criteria and policies for all hydraulic analyses performed by the Department. The Unit does not typically check the analyses performed by the designer; however, the Unit serves as a technical resource as needed.

28-1.02(02) Consultant-Designed Projects

For those projects designed by consultants, the following summarizes the division of responsibilities:

1. Consultant. In general, the consultant is responsible for the following:

   a. all hydrologic and hydraulic computations for local transportation projects; and

   b. all hydrologic and hydraulic computations on INDOT projects related to storm drains and culverts except those titled in the system as "small structure replacement."

   Consultants are responsible for performing their analyses consistent with the policies and criteria adopted by the Department. The Consultant must submit its calculations to the INDOT Project Manager for the design file for the following:

   a. culverts with diameters equal to or less than 900 mm or equivalent area deformed pipes, and

   b. storm drains.

2. Hydraulics Unit. For roadway drainage appurtenances, the Hydraulics Unit:

   a. reviews the consultant's computations for culverts which are greater than 900 mm in diameter or equivalent area deformed pipe,

   b. reviews the consultant's computations for projects in urban areas where the drainage basin exceeds 80 ha, and

   c. performs computations for INDOT projects listed as "small structure replacement."

   The Hydraulics Unit does not review storm drain calculations except in urban areas where the drainage basin exceeds 80 ha.

For bridge waterway openings, the Hydraulics Unit:

a. reviews all bridge hydraulic computations performed by the consultant for local projects,

b. reviews scour computations performed by the consultant for local projects, and

c. performs all bridge hydraulic computations for all INDOT projects.

28-1.02(03) Pipe Classification System

Section 28-6.0 discusses the responsibilities of designers specifically for the INDOT Pipe Classification System.

28-2.0 AASHTO MODEL DRAINAGE MANUAL

The AASHTO Task Force on Hydrology and Hydraulics has produced the *Model Drainage Manual* (*MDM*) for use by State Departments of Transportation nationwide. The *MDM* presents design theories, concepts, guidelines, criteria, policies and procedures for use by the hydraulics designer. It has been prepared in a format suitable for direct use, with State-specific modifications, by any State DOT.

Part IV has been prepared based on the AASHTO *MDM*. Where practical, the text and graphics in the *MDM* have been incorporated into the *Indiana Manual* with modifications to reflect INDOT practices. The following summarizes the disposition of each chapter of the *MDM* in the *Indiana Design Manual*:

1. Chapter One "Introduction". Chapter One is not incorporated into the *Indiana Design Manual*.

2. Chapter Two "Legal Aspects". Chapter Two has been edited and incorporated into Section 28-3.0.

3. Chapter Three "Policy". Sections 3.1 and 3.2 in Chapter Three have been edited and incorporated into Section 28-4.0.

4. Chapter Four "Documentation". Chapter Four has been edited and incorporated into Section 28-5.0 of the *Indiana Design Manual*.

5. Chapter Five "Planning and Location". The *Indiana Design Manual* references Chapter Five of the *MDM*.

6. Chapter Six "Data Collection". Part III discusses data collection for drainage surveys based on Chapter Six of the *MDM*.

7. Chapter Seven "Hydrology". Chapter Seven has been used as a resource for the development of Chapter Twenty-nine.

8. Chapter Eight "Channels". Chapter Eight has been edited and incorporated into Chapter Thirty.

9. Chapter Nine "Culverts". Chapter Nine has been edited and incorporated into Chapter Thirty-one.

10. Chapter Ten "Bridges". Chapter Ten has been used as a resource for the development of Chapters Thirty-two and Thirty-three.

11. Chapter Eleven "Energy Dissipators". Chapter Eleven has been edited and incorporated into Chapter Thirty-four.

12. Chapter Twelve "Storage Facilities". Chapter Twelve has been edited and incorporated into Chapter Thirty-five.

13. Chapter Thirteen "Storm Drainage Systems". Chapter Thirteen has been edited and incorporated into Chapter Thirty-six.

14. Chapter Fourteen "Pump Stations". The *Indiana Design Manual* references Chapter Fourteen of the *MDM*.

15. Chapter Fifteen "Surface Water Environment". The *Indiana Design Manual* references Chapter Fifteen of the *MDM.*

16. Chapter Sixteen "Erosion and Sediment Control". Chapter Sixteen has been used as a resource for the development of Chapter Thirty-seven.

17. Chapter Seventeen "Bank Protection". Chapter Seventeen has been edited and incorporated into Chapter Thirty-eight.

18. Chapter Eighteen "Coastal Zone". Chapter Eighteen is not applicable to Indiana.

19. Chapter Nineteen "Construction". The *Indiana Design Manual* references Chapter Nineteen of the *MDM*.

20. Chapter Twenty "Maintenance of Drainage Facilities". The *Indiana Design Manual* references Chapter Twenty of the *MDM*.

21. Chapter Twenty-one "Restoration". The *Indiana Design Manual* references Chapter Twenty-one of the *MDM*.

28-3.0 LEGAL ASPECTS

28-3.01 Overview

Various drainage laws and rules applicable to highway facilities are discussed in this Section. It should not be treated as a basis for legal advice or legal decisions. It is not a summary of all existing drainage laws and, most emphatically, is not intended as a substitute for legal counsel.

The following generalizations can be made for drainage liability.

1. A goal in highway drainage design should be to perpetuate natural drainage, as practical.

2. The courts look with disfavor upon infliction of injury or damage that could reasonably have been avoided by a prudent designer, even where some alteration in flow is legally permissible.

3. The laws relating to the liability of government entities are undergoing radical change, with a trend toward increased government liability.

The descending order to law supremacy is Federal, State and local and, except as provided for in the statutes or constitution of the higher level of government, the superior level is not bound by laws, rules or regulations of a lower level. The following sections summarize the role of drainage law at each level of government.

28-3.02 Federal Laws

28-3.02(01) General

Federal law consists of the Constitution of the United States, Acts of Congress, regulations which government agencies issue to implement these acts, Executive Orders issued by the President, and case law. Compilations of Federal Statutory Law, revised annually, are available in the United States Code (USC) and the United States Code Service (USCS). Compilations of Federal regulatory material, revised annually, are available in the Code of Federal Regulations (CFR).

Federal law does not address drainage per se, but many laws have implications which affect drainage design. These include laws concerning the following:

1. flood insurance and construction in flood hazard areas,
2. navigation and construction in navigable waters,
3. water pollution control,
4. environmental protection, and
5. protection of fish and wildlife.

Federal agencies formulate and promulgate rules and regulations to implement these laws, and highway hydraulic designers should attempt to remain informed on proposed and final regulations.

28-3.02(02) Navigable Waters Regulations

The Congress of the United States is granted constitutional power to regulate Interstate commerce, including navigable waters. Basically, four Federal agencies implement existing Federal regulations:

1. Coast Guard. The USCG has regulatory authority under Section 9 of the Rivers and Harbors Act of 1899, 33 U.S.C. 401 to approve plans and issue permits for bridges and causeways across navigable rivers. FHWA has the responsibility to determine that a USCG permit is not required. The USCG has the responsibility for the following:

    a. to determine whether or not a USCG permit is required for the improvement or construction of a bridge over navigable waters except for the exemption exercised by FHWA, and

    b. to approve the bridge location, alignment and appropriate navigational clearances in all bridge permit applications.

2. Corps of Engineers. The U.S. Army Corps of Engineers has regulatory authority over the construction of dams, dikes or other obstructions (which are not bridges and causeways)

under Section 9 (33 U.S.C. 401). The Corps also has authority to regulate Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403), which prohibits the alteration or obstruction of any navigable waterway with the excavation or deposition of fill material in such waterway. In addition, Section 404 of the Clean Water Act (33 U.S.C. 1344) prohibits the unauthorized discharge of dredged or fill material into waters of the United States, including navigable waters. Such discharges require a Permit. The term "discharges of fill material" means the addition of rock, sand, dirt, concrete or other material into the waters of the United States incidental to the construction of any structure. The Corps of Engineers has granted Nationwide General Permits for certain categories of minor activities involving discharge of fill material. Otherwise, an Individual 404 Permit is required.

3. Federal Highway Administration. The Federal Highway Administration has the authority to implement the Section 404 Permit Program (Clean Water Act of 1977) for Federal-aid highway projects processed under 23 CFR 771.115 (b) categorical exclusions. This permit is granted for projects where the activity, work or discharge is categorically excluded from environmental documentation because such activity does not have an individual or cumulative significant effect on the human environment.

4. Environmental Protection Agency (EPA). The EPA is authorized to prohibit the use of any area as a disposal site when it is determined that the discharge of materials at the site will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas, wildlife or recreational areas (Section 404 (c)), Clean Water Act (33 U.S.C. 1344). Also EPA is authorized under Section 402 of the Clean Water Act (33 U.S.C. 1344) to administer and issue a "National Pollutant Elimination Discharge System" (NPDES) Permit for point source discharges, provided prescribed conditions are met.

See Chapter Nine for more information on permits.

28-3.02(03) Fish and Wildlife Service

The Fish and Wildlife Act of 1956 (16 U.S.C. 742 et seq.), the Migratory Game-Fish Act (16 U.S.C. 760c-760g), and the Fish and Wildlife Coordination Act (16 U.S.C. 611-666c) express the concern of Congress with the quality of the aquatic environment as it affects the conservation, improvement and enjoyment of fish and wildlife resources. The Fish and Wildlife Coordination Act requires that:

> *whenever the waters of any stream or body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose whatever, including*

navigation and drainage, by any department or agency of the United States, or by any public or private agency under Federal permit or license, such department or agency shall first consult with the United States Fish and Wildlife Service, Department of the Interior, and with the head of the agency exercising administration over the wildlife resources of the particular state with a view to the conservation of wildlife resources by preventing loss of and damage to such resources as well as providing for the development and improvement thereof.

The Fish and Wildlife Service's role in the permit review process is to review and comment on the effects of a proposal on fish and wildlife resources. It is the function of the regulatory agency (e.g., Corps of Engineers, U. S. Coast Guard) to consider and balance all factors, including anticipated benefits and costs in accordance with NEPA, in deciding whether to issue the permit.

28-3.02(04) National Flood Insurance Program (NFIP)

The Flood Disaster Protection Act of 1973 denies Federal financial assistance to flood-prone communities that fail to qualify for flood insurance. The Act requires communities to adopt certain land use controls to qualify for flood insurance. These requirements could impose restrictions on the construction of highways in flood plains and floodways in communities which have qualified for flood insurance. A floodway is that portion of the flood plain required to pass a flood that has a 1-percent chance (i.e., a 100-year flood) of occurring in any 1-year period without cumulatively increasing the water surface elevation more than the allowable backwater. See Chapter Thirty-two for specific INDOT / IDNR criteria.

Flood Insurance

The National Flood Insurance Act of 1968 requires that communities adopt adequate land use and control measures to qualify for insurance. Federal criteria promulgated to implement this provision contain the following requirements which can affect certain highways.

1. In riverine situations, the community must require that, until a floodway has been designated, no use, including land fill, be permitted within the flood plain area having special flood hazards for which base flood elevations have been provided, unless it is demonstrated that the cumulative effect of the proposed use, when combined with all other existing and reasonably anticipated uses of a similar nature, will not increase the water surface elevation of the 100-year flood more than the allowable backwater at any point within the community.

2. After the flood plain area having special flood hazards has been identified and the water surface elevation for the 100-year flood and floodway data have been provided, the community must designate a floodway which will convey the 100-year flood without increasing the water surface elevation of the flood more than the allowable backwater at any point and prohibit, within the designated floodway, fill, encroachments and new construction and substantial improvements of existing structures which would result in any increase in flood heights within the community during the occurrence of the 100-year flood discharge.

See Chapter Thirty-two for specific INDOT / IDNR criteria.

The local community with land use jurisdiction has the responsibility for enforcing National Flood Insurance Program (NFIP) regulations in that community if the community is participating in the NFIP. Consistency with NFIP standards is a requirement for Federal-aid highway actions involving regulatory floodways. The community, by necessity, must submit proposals to the Federal Emergency Management Agency (FEMA) for amendments to NFIP ordinances and maps in that community should it be necessary. Determination of the status of a community's participation in the NFIP and review of applicable NFIP maps and ordinances are, therefore, essential first steps in conducting location hydraulic studies and preparing environmental documents.

NFIP Maps

Where NFIP maps are available, their use is mandatory in determining whether a highway location alternative will include an encroachment on the base flood plain. Three types of NFIP maps are published.

1. Flood Hazard Boundary Map (FHBM),
2. Flood Boundary and Floodway Map (FBFM), and
3. Flood Insurance Rate Map (FIRM).

A FHBM is generally not based on a detailed hydraulic study and, therefore, the flood plain boundaries shown are approximate. A FBFM, on the other hand, is generally derived from a detailed hydraulic study and should provide reasonably accurate information. The hydraulic data from which the FBFM was derived are available through the regional office of FEMA. This is normally in the form of computer input data records for calculating water surface profiles. The FIRM is generally produced at the same time using the same hydraulic model and has appropriate rate zones and base flood elevations added.

Communities may or may not have published one or more of the above maps depending on their level of participation in the NFIP. Information on community participation in the NFIP is

provided in the "National Flood Insurance Program Community Status Book" which is published semiannually for each State.

28-3.03 State Drainage Law

28-3.03(01) Types

State drainage law is derived mainly from two sources as follows:

1. Common Law. Common law is that body of principles which developed from immemorial usage and custom and which receives judicial recognition and sanction through repeated application. These principles were developed without legislative action and are embodied in the decisions of the courts.

2. Statutory Law. Statutory laws of drainage are enacted by legislatures to enlarge, modify, clarify or change the common law applicable to particular drainage conditions. This type of law is derived from constitutions, statutes, ordinances and codes.

In general, the common law rules of drainage predominate unless they have been enlarged or superseded by statutory law.

28-3.03(02) Classification of Waters

The first step in the evaluation of a drainage problem is to classify the water as surface water, stream water, flood water or groundwater. Once the classification has been established, the rule that applies to the particular class of water determines responsibilities with respect to disposition of the water. The following definitions apply.

1. Surface Waters. Surface waters are those waters which have been precipitated on the land from the sky or forced to the surface in springs and which have then spread over the surface of the ground without being collected into a definite body or channel.

2. Stream Waters. Stream waters are former surface or ground waters which have entered and now flow in a well-defined natural watercourse, together with other waters reaching the stream by direct precipitation or rising from springs in the bed or banks of the watercourse. Legally, a watercourse refers to a definite channel with bed and banks within which water flows either continuously or intermittently.

3. Flood Waters. Flood waters are former stream waters which have escaped from a watercourse (and its overflow channels) and flow or stand over adjoining lands. They remain flood waters until they disappear from the surface by infiltration or evaporation or return to a natural watercourse.

4. Ground Waters. In legal considerations, ground waters are divided into two classes — percolating waters and underground streams. The term "percolating waters" generally includes all waters which pass through the ground beneath the surface of the earth without a definite channel. The general rule is that all underground waters are presumed to be percolating and, to remove them from the percolating class, the existence and course of a permanent channel must be clearly shown. Underground streams are waters passing through the ground beneath the surface in permanent, distinct, well-defined channels.

28-3.04 State Water Rules

28-3.04(01) Basic Concepts

Two major rules have been developed by the courts regarding the disposition of surface waters. One is known as the civil law rule of natural drainage. The other is referred to as the common enemy doctrine. Much of the law regarding stream waters is founded on a common law maxim that states "water runs and ought to run as it is by natural law accustomed to run." Thus, as a general rule, any interference with the flow of a natural watercourse to the injury or damage of another will result in liability. However, there are qualifications as follows:

1. In common law, flood waters are treated as a "common enemy" of all people, lands and property attacked or threatened by them.

2. In ground water law, the "English Rule," which is analogous to the common enemy rule in surface water law, is based on the doctrine of absolute ownership of water beneath the property by the landowner.

28-3.04(02) Surface Waters

The civil law rule is based upon the perpetuation of natural drainage. The rule places a natural easement or servitude upon the lower land for the drainage of surface water in its natural course, and the natural flow of the water cannot be obstructed by the servient owner to the detriment of the dominant owner. The State of Indiana has modified this rule so that the owner of upper lands

has an easement over lower lands for drainage of surface waters, and natural drainage conditions can be altered by an upper proprietor provided the water is not sent down in a manner or quantity to do more harm than formerly. The following also applies.

1. Under the common enemy doctrine, surface water is regarded as a common enemy which each property owner may fight off or control as he will or is able, either by retention, diversion, repulsion or altered transmission. Thus, there is not necessarily cause of action even if some injury occurs causing damage. This doctrine has been subject to a limitation that one must use his land so as not to unreasonably or unnecessarily damage the property of others.

2. Under the reasonable use rule, each property owner can legally make reasonable use of his land, even though the flow of surface waters is altered thereby and causes some harm to others. However, liability attaches when his harmful interference with the flow of surface water is "unreasonable." Whether a landowner's use is unreasonable is determined by a nuisance-type balancing test. The analysis involves several questions as follows:

    a. Was there reasonable necessity for the actor to alter the drainage to make use of his land?

    b. Was the alteration done in a reasonable manner?

    c. Does the utility of the actor's conduct reasonably outweigh the gravity of harm to others?

28-3.04(03) Stream Waters

Where natural watercourses are unquestioned in fact and in permanence and stability, there is little difficulty in application of the rule. Highways cross channels on bridges or culverts, usually with some constriction of the width of the channel and obstruction by substructure within the channel, both causing backwater upstream and acceleration of flow downstream. The changes in regime must be so small as to be tolerable by adjoining owners, or there may be liability of any injuries or damages suffered.

Surface waters from highways are often discharged into the most convenient watercourse. The right is unquestioned if those waters were naturally tributary to the watercourse and unchallenged if the watercourse has adequate capacity. However, if all or part of the surface waters have been diverted from another watershed to a small watercourse, any lower owner may complain and recover for ensuing damage.

28-3.04(04) Flood Waters

Considering flood waters as a common enemy permits all affected landowners, including owners of highways, to act in any reasonable way to protect themselves and their property from the common enemy. They may obstruct its flow from entering their land, backing or diverting water onto lands of another without penalty, by gravity or pumping, by diverting dikes or ditches, or by any other reasonable means.

Again, the test of "reasonableness" has frequently been applied, and liability can result where unnecessary damage is caused. Ordinarily, the highway designer should make provision for overflow in areas where it is foreseeable that it will occur. There is a definite risk of liability if such waters are impounded on an upper owner or, worse yet, are diverted into an area where they would not otherwise have gone. Merely to label waters as "flood waters" does not mean that they can be disregarded.

The "English Rule" has been modified by the "Reasonable Use Rule" which states in essence that each landowner is restricted to a reasonable exercise of his own right and a reasonable use of his property in view of the similar right of his neighbors.

The key word is "reasonable." Although this may be interpreted somewhat differently from case to case, it generally means that a landowner can utilize subsurface water on his property for the benefit of agriculture, manufacturing, irrigation, etc., pursuant to the reasonable development of his property although such action may interfere with the underground waters of neighboring proprietors. However, it does generally preclude the withdrawal of underground waters for distribution or sale for uses not connected with any beneficial ownership or enjoyment of the land from whence they were taken.

A further interpretation of "reasonable" in relation to highway construction would view the excavation of a deep "cut section" that intercepts or diverts underground water to the detriment of adjacent property owners as unreasonable. There are also cases where highway construction has permitted the introduction of surface contamination into subsurface waters and thus incurred liability for resulting damages.

28-3.05 Statutory Law

The inadequacies of the common law or court-made laws of drainage has led to a gradual enlargement and modification of the common law rules by legislative mandate. If the common

law rules have been enlarged or superseded by statutory law, the statute prevails. In general, statutes have been enacted that affect drainage as described below.

28-3.05(01) Eminent Domain

In the absence of an existing right, public agencies may acquire the right to discharge highway drainage across adjoining lands through the use of the right of eminent domain. Eminent domain is the power of public agencies to take private property for public use.

The Indiana State constitution grants Indiana the right of eminent domain which allows that taking of property for public purposes, including the development of watercourse and watershed areas. However, whenever any property is taken under eminent domain, the private landowner must be compensated for his loss.

28-3.05(02) Water Rights

The water right which attaches to a watercourse is a right to the use of the flow, not ownership of the water itself. This is true under both the riparian doctrine and the appropriation doctrine. This right of use is a property right, entitled to protection to the same extent as other forms of property, and is regarded as real property. After the water has been diverted from the stream flow and reduced to possession, the water itself becomes the personal property of the riparian owner or the appropriator. The following applies.

1. Riparian Doctrine. Under the riparian doctrine, lands contiguous to watercourses have prior claim to waters of the stream solely by reason of location and regardless of the relative productive capacities of riparian and non-riparian lands.

2. Doctrine of Prior Appropriation. The essence of this doctrine is the exclusive right to divert water from a source when the water supply naturally available is not sufficient for the needs of all those holding rights to its use. Such exclusive right depends upon the effective date of the appropriation, the first in time being the first in right.

Generally, highway designers must consider that proposed work in the vicinity of a stream should not impair either the quality or quantity of flow of any water rights to the stream.

28-3.06 Local Laws and Applications

Local governments (cities, counties, improvement districts) have ordinances and codes which require consideration during design. For example, zoning ordinances can have a substantial effect on the design of a highway and future drainage from an area. Generally, the State is not legally required to comply with local ordinances except where compliance is required by specific State statute. However, INDOT will, as practical, conform with local ordinances as a courtesy, especially when it can be done without imposing a burden on the State.

A municipality is generally treated as a private party in State drainage matters. A municipality undertaking a public improvement is liable like an individual for damage resulting from negligence or an omission of duty. As a general rule, municipalities are under no legal duty to construct drainage improvements unless public improvements necessitate drainage (e.g., where street construction accelerates or alters storm runoff). In addition, it is generally held that municipalities are not liable for adoption or selection of a defective plan of drainage.

Municipalities can be held liable for negligent construction of drainage improvements, for negligent maintenance and repair of drainage improvements, or if it fails to provide a proper outlet for drainage improvements. In general, in the absence of negligence, a municipality will not be held liable for increased runoff occasioned by the necessary and desirable construction of storm drains, nor will a municipality be held liable for damages caused by overflow of its storm drains occasioned by extraordinary, unforeseeable rains or floods. Municipal liability will attach where a municipality does the following:

1. collects surface water and casts it in a body onto private property where it did not formerly flow;

2. diverts, by means of artificial drains, surface water from the course it would otherwise have taken, and casts it in a body large enough to do substantial injury on private land where, but for the artificial storm drain, it would not go; and

3. fills up, dams back or otherwise diverts a stream of running water so that it overflows its banks and flows on the land of another.

28-3.07 Legal Drains

Most counties in Indiana have established a set of legal drains which are maintained by the County Surveyor. Indiana law gives the counties certain privileges where a project impacts an established legal drain. More detailed information on legal drain regulations can be found in IC 36-2-12-15 and IC 36-9-27.

At the initiation of any bridge or road project, the designer should contact the appropriate County Surveyor's office to determine whether any affected waterways are legal drains. If any waterway is a legal drain, the designer should invite the County Surveyor to all field checks. This will provide an adequate opportunity for the Surveyor to express concerns and provide comments on the project. The designer should also request any available information regarding legal flow lines or other requirements. This information must be included with the grade review plans. If not, then include a note on the telephone conversation stating that the waterway is not a legal drain.

28-4.0 POLICY

28-4.01 Introduction

28-4.01(01) Purpose

Drainage concerns are one of the most important aspects of highway design and construction. The purpose of this Section is to briefly outline specific policies that guide and determine the multitude of variables which influence drainage design.

28-4.01(02) Policy vs. Criteria

Policy and criteria statements are frequently closely related; criteria is INDOT's numerical or specific guidance which is founded in broad policy statements. For this *Manual*, the following definitions of policy and criteria apply.

1. Policy. A definite course of action or method of action selected to guide and determine present and future decisions.

2. Design Criteria. The standards by which a policy is implemented or placed in action.

Thus, design criteria are needed for design; policy statements are not. Following is an example of a policy statement:

> *The designer will size the drainage structure to accommodate a flood compatible with the projected traffic volumes.*

The design criteria for designing the structure might be as follows:

For projected traffic volumes less than or equal to 750 vehicles per day, drainage structures shall be designed for a 10-year flood (exceedence probability of 10%). For projected traffic volumes greater than 750 vehicles per day, a drainage structure shall be designed for a 25-year flood (exceedence probability of 4%).

The following sections will present information on the hydraulic design of drainage structures and related Federal, State and local policies. Some sections will be limited to outlining the relevant policies (with references indicating where details can be obtained) while other sections will state the policies and give detailed information.

28-4.02 General Hydraulic Design Policies

28-4.02(01) Introduction

An adequate drainage structure may be defined as one which meets the following policies.

1. the design of the structure meets or exceeds INDOT standard engineering practice, and

2. the design is consistent with what a reasonably competent and prudent designer would do under similar circumstances.

The studies listed below are normally conducted as a part of the design of highway drainage structures and serve as a means of achieving an adequate drainage design.

1. hydrologic and hydraulic analysis, and
2. engineering evaluation of selected alternatives.

These studies are discussed further in the following sections.

28-4.02(02) Hydrologic Analysis

Present state-of-practice formulas and models for estimating flood flows are based on statistical analyses of rainfall and runoff records. The recommended practice is for the designer to select appropriate hydrologic estimating procedures and obtain runoff data where available for purposes of evaluation, calibration and determination of the predicted value of the desired flood frequencies. The predicted value of the flood flows represents the designer's best estimate, with

varying degrees of error. The expected magnitude of this variation can be determined for some formulas or models as a part of the hydrologic design procedure.

28-4.02(03) Hydraulic Analysis

The next step in the design process involves preliminary selections of alternative designs that are judged to meet the site conditions and to accommodate the flood flows selected for analysis. The hydraulic analysis is made utilizing appropriate formulas, physical models or computer programs for purposes of defining, calibrating and checking the performance of the preliminary designs over a range of flows.

28-4.02(04) Engineering Evaluation

The final step in the design process is the engineering evaluation of the preliminary designs and approval of the selected final design. This process involves consideration and balancing of a number of factors. Some of these factors are as follows:

1. legal considerations,
2. flood hazards to highway users and neighboring property owners,
3. hydraulic efficiencies,
4. costs,
5. environmental and social concerns, and
6. other site-specific concerns.

28-4.02(05) General Policies

Hydrologic and hydraulic analyses set forth the design process representative of INDOT's present "standard engineering practice." Engineering evaluation outlines the approach to be followed by a "reasonably competent and prudent designer" in evaluating, selecting and approving a final design. The following policies are made regarding this design process.

1. It is the designer's responsibility to provide an adequate drainage structure. The designer is not required to provide a structure that will accommodate all conceivable flood flows under all possible site conditions.

2. The detail of design studies should be commensurate with the risk associated with the encroachment and with other economic, engineering, social or environmental concerns.

3. The overtopping and/or design flood may serve as criteria for evaluating the adequacy of a proposed design. The "overtopping flood" is the smallest recurrence interval flood which will result in flow over the highway or other watershed boundary. The overtopping flood flow is the flow that overtops the highway or other watershed boundary limit. The "design flood" is the recurrence interval of the flood for which the drainage structure is sized to ensure that no traffic interruption or significant damage will result. The overtopping flood and the design flood may vary widely depending on the grade, alignment and classification of the road and the characteristics of the watercourse and flood plain.

4. The predicted value of the 100-year or base flood serves as the present engineering standard for evaluating flood hazards and as the basis for regulating flood plains under the National Flood Insurance Program. The designer must make a professional judgment on the degree of risk that is tolerable for the base flood on a case-by-case basis.

5. The developed hydraulic performance curve of a drainage structure depicts the relationship between floodwater stage (or elevation) and flood-flow magnitudes and frequencies. The performance curve should include the 100-year flood. With the performance curve, the designer can evaluate the adequacy of the design for a range of flows and consider errors of estimate in the hydrologic estimating procedure. It is standard engineering practice to use the predicted value of the 100-year flood as the basis for evaluating flood hazards; however, flows larger than this value may be considered for complex, high-risk or unusual cases that require special studies or risk analyses.

28-4.03 Water Main and Sanitary Sewer Construction

The Standard Specifications do not include most elements related to the construction of water main and sanitary sewer construction. However, many contracts, mostly those for local public agencies, include construction of these facilities. Therefore, special provisions should be developed and included in individual contracts. These special provisions should adequately describe the work, determine material and construction requirements, and establish methods to measure and pay for the work.

There are many reference materials available from which information can be obtained to assist in the preparation of any required special provision. One such reference is the *Model Specifications For Water and Sewer Main Construction In Indiana*, prepared as a result of a joint effort between the Consulting Engineers of Indiana, Inc., Purdue University, and Indiana Constructors, Inc. Other such reference documents have been prepared by individual public and privately owned entities.

The designer is free to develop a project-specific special provision from scratch or incorporate any document into a contract by reference. In either case, the work must be completely covered by the special provision as described in the last sentence of the first paragraph of this memorandum. In addition, if a document is incorporated into a contract by reference, the special provision must indicate that the Standard Specifications govern in all cases where there is conflict with the referenced document. The designer should also be certain that the referenced document is readily available for use by the contractor or field personnel. The designer may indicate in a special provision how or where the document may be obtained.

28-5.0 DOCUMENTATION

28-5.01 Overview

28-5.01(01) Introduction

An important part of the design or analysis of any hydraulic facility is its documentation. Appropriate documentation of the design of any hydraulic facility is essential because of the following:

1. the importance of public safety;

2. justification of expenditure of public funds;

3. future reference by engineers (when improvements, changes or rehabilitations are made to the highway facilities);

4. information leading to the development of defense in litigation; and

5. public information.

Occasionally, it is necessary to refer to plans, specifications and analyses long after the actual construction has been completed. Documentation permits evaluation of the performance of structures after flood events to determine if the structures performed as anticipated or to establish the cause of unexpected behavior, if such is the case. In the event of a failure, it is essential that contributing factors be identified in order that recurring damage can be avoided.

28-5.01(02) Definition

The definition of hydrologic and hydraulic documentation as used in this Section is the compilation and preservation of the design and related details and all pertinent information on which the design and decisions were based. This shall include the drainage area and other maps, field survey information, source references, photographs, engineering calculations and analyses, measured and other data, and flood history including narratives from newspapers and individuals such as highway maintenance personnel and local residents who witnessed or had knowledge of an unusual event.

28-5.01(03) Purpose

This Section presents the documentation which shall be included in the design files and on the construction plans. Although the Department's documentation requirements for existing and proposed drainage facilities are similar, the data retained for existing facilities are often slightly different than that for proposed facilities, and these differences are discussed. This Section focuses on the documentation of the findings obtained in using the other chapters of this *Manual* and, thus, designers shall be familiar with all the hydrologic and hydraulic design procedures associated with this Section. This Section identifies the Department's system for organizing the documentation of hydraulic designs and reviews to provide as complete a history of the design process as is practical.

The major purpose of providing good documentation is to define the design procedure that was used and to show how the final design and decisions were arrived at. Often, there is expressed the myth that avoiding documentation will prevent or limit litigation losses as it supposedly precludes providing the plaintiff with incriminating evidence. This is seldom if ever the case, and documentation should be viewed as the record of reasonable and prudent design analysis based on the best available technology. Thus, good documentation can provide the following:

1. protecting the Department by proving that reasonable and prudent actions were, in fact, taken (such proof should certainly not increase the potential court award and may decrease it by disproving any claims of negligence by the plaintiff);

2. identifying the situation at the time of design which might be very important if legal action occurs in the future;

3. documenting that rationally accepted procedures and analyses were used at the time of the design which were commensurate with the perceived site importance and flood hazard (this should further disprove any negligence claims);

4. providing a continuous site history to facilitate future reconstruction;

5. providing the file data necessary to quickly evaluate any future site problems that might occur during the facilities service life; and

6. expediting plan development by clearly providing the reasons and rationale for specific design decisions.

28-5.01(04) Types

There are three basic types of documentation which should be considered — preconstruction, design, and construction or operation.

1. Preconstruction documentation shall include the following, if available, or within the budgetary restraints of the project.

    a. aerial photographs;

    b. contour mapping;

    c. watershed map or plan including flow directions, watershed boundaries and watershed areas;

    d. surveyed data reduced to include existing hydraulic facilities, existing controls, profiles (roadway, channel, driveways) and cross sections (roadway, channels, faces of structures);

    e. flood insurance studies and maps by FEMA;

    f. Natural Resource Conservation Service soil maps;

    g. field trip report(s) which may include video cassette recordings, audio tape recordings, still camera photographs, movie camera films and written analysis of findings with sketches; and

    h. reports from other agencies (local, State or Federal), INDOT personnel, newspapers and abutting property owners.

2. Design documentation shall include all the information used to justify the design, including the following:

a. reports from other agencies,
b. hydrological report,
c. hydraulic report, and
d. approvals.

3. Construction or operation documentation shall include the following:

a. plans;
b. revisions;
c. as-built plans and subsurface borings;
d. photographs; and
e. record of operation during flooding events, complaints and resolutions.

It is very important to prepare and maintain in a permanent file the as-built plans for every drainage structure to document subsurface foundation elements such as footing types and elevations, pile types, (driven) tip elevations, etc. There may be other information which should be included or may become evident as the design or investigation develops. This additional information shall be incorporated at the discretion of the designer.

28-5.01(05) Scheduling

Documentation shall not be considered as occurring at specific times during the design or as the final step in the process, which could be long after the final design is completed. Documentation should rather be an ongoing process and part of each step in the hydrologic and hydraulic analysis and design process. This will increase the accuracy of the documentation, provide data for future steps in the plan development process, and provide consistency in the design even when different designers are involved at different times of the plan development process.

28-5.01(06) Responsibility

The designer shall be responsible for determining what hydrologic analyses, hydraulic design and related information shall be documented during the plan development process. The designer shall make a determination that complete documentation has been achieved during the plan development process which will include the final design. To assist in this determination, refer to Section 28-5.04.

28-5.02 Procedures

28-5.02(01) Introduction

A complete hydrologic and hydraulic design and analysis documentation file for each waterway encroachment or crossings shall be maintained by the Hydraulics Unit. Where practical, this file shall include such items as follows:

1. identification and location of the facility;
2. photographs (ground and aerial);
3. hydrologic investigations;
4. drainage area maps, vicinity maps and topographic maps;
5. contour maps;
6. interviews (local residents, adjacent property owners and maintenance forces);
7. newspaper clippings;
8. design notes and correspondence relating to design decisions;
9. history of performance of existing structure(s); and
10. assumptions.

The documentation file shall contain design/analysis data and information which influenced the facility design.

28-5.02(02) Practices

Following are the Department's practices related to documentation of hydrologic and hydraulic designs and analyses.

1. Hydrologic and hydraulic data, preliminary calculations and analyses, and all related information used in developing conclusions and recommendations related to drainage requirements, including estimates of structure size and location, shall be compiled in a documentation file.

2. The designer shall document all design assumptions and selected criteria including the decisions related thereto.

3. The amount of detail of documentation for each design or analysis shall be commensurate with the risk and the importance of the facility.

4. Documentation shall be organized to be as concise and complete as practicable so that knowledgeable designers can understand years hence what was done by predecessors.

5. Circumvent incriminating statements wherever possible by stating uncertainties in less than specific terms (e.g., the culvert may back water rather than the culvert will back water).

6. Provide all related references in the documentation file to include such things as published data and reports, memos and letters, and interviews. Include dates and signatures where appropriate.

7. Documentation shall include data and information from the conceptual stage of project development through construction to provide successors with all information.

8. Documentation shall be organized to logically lead the reader from past history through the problem background, into the findings, and through the performance.

9. A summary at the beginning of the documentation will provide an outline of the documentation file to assist users in finding detailed information.

28-5.03 Documentation Procedures

28-5.03(01) Introduction

The following items shall be included in the documentation file. The intent is not to limit the data to only those items listed but, rather, establish a minimum requirement consistent with the hydraulic design procedures as outlined in this *Manual*. If circumstances are such that the drainage facility is sized by other than normal procedures or if the size of the facility is governed by factors other than hydrologic or hydraulic factors, a narrative summary detailing the design basis shall appear in the documentation file. Additionally, the designer shall include in the documentation file items not listed below but which are useful in understanding the analysis, design, findings and final recommendations.

28-5.03(02) Hydrology

The following items used in the design or analysis shall be included in the documentation file.

1. contributing watershed area size and identification of source (map name, etc.);

2. hydrologic discharge and hydrograph estimating method and findings;

3. IDNR Recommendation Letter (when an IDNR permit is required); and

4. method for estimating 500-year discharge (when applicable).

28-5.03(03) Bridges

The following items shall be included in the documentation file.

1. 100-year highwater for natural, existing and proposed conditions;

2. cross section(s) used in the design highwater determination;

3. roughness coefficient ("n" value) assignments;

4. information on the method used for design highwater determination;

5. observed highwater, dates and discharges;

6. velocity measurements or estimates and locations (include both the through-bridge and channel velocity) for the 100-year flood;

7. calculated backwater, velocity and scour for the 100-year flood and 500-year flood for scour evaluation;

8. magnitude and frequency of overtopping flood;

9. copies of computer analyses (existing and proposed) and 3.5″ disk containing all data files;

10. complete hydraulic study report;

11. economic analysis of design and alternatives;

12. bridge scour results;

13. roadway geometry (plan and profile); and

14. potential flood hazards to adjacent properties.

28-5.03(04) Culverts

The following items shall be included in the documentation file.

1. culvert performance curves;

2. allowable headwater elevation and basis for its selection;

3. cross section(s) used in the design highwater determinations;

4. roughness coefficient assignments (“n” values);

5. observed highwater, dates and discharges;

6. stage-discharge curve for natural, existing and proposed conditions to include the depth and velocity measurements or estimates and locations for the 100-year flood;

7. performance curves showing the calculated backwater elevations, outlet velocities and scour (if applicable), and the 100-year flood;

8. type of culvert entrance condition;

9. culvert outlet appurtenances and energy dissipation calculations and designs (if applicable);

10. copies of all computer analyses and a 3.5″ disk containing all data files;

11. roadway geometry (plan and profile); and

12. potential flood hazard to adjacent properties.

28-5.03(05) Open Channels

The following items shall be included in the documentation file.

1. stage-discharge curves for the 100-year and any historical water surface elevation(s);

2. cross section(s) used in the design water surface determinations and their locations;
3. roughness coefficient assignments (“n” values);
4. information on the method used for design water surface determinations;
5. observed highwater, dates and discharges;
6. channel velocity measurements or estimates and locations;
7. water surface profiles through the reach for the 100-year and any historical floods;
8. design or analysis of materials proposed for the channel bed and banks;
9. energy dissipation calculations and designs; and
10. copies of all computer analyses, including 3.5″ data disks.

28-5.03(06) Storm Drains

The following items shall be included in the documentation file.

1. computations for inlets and pipes, including hydraulic grade lines;

2. copies of the standard computation sheets given in Chapter Thirty-six or the computer printout;

3. complete drainage area map;

4. design frequency (10-year gravity and 50-year pressure flow);

5. information concerning outfalls, existing storm drains and other design considerations; and

6. a schematic indicating storm drain system layout.

28-5.03(07) Pump Stations

The following items shall be included in the documentation file.

1. inflow design hydrograph from drainage area to pump,
2. flood-frequency curve for the attenuated peak discharge,
3. maximum allowable headwater elevations and related probable damage,
4. starting sequence and elevations,
5. sump dimensions,
6. available storage amounts,

7. pump sizes and operations,
8. pump calculations and design report, and
9. line storage and pit storage capacity.

28-5.03(08) Computer Files

The following items shall be included in the documentation file and be clearly labeled.

1. input data listing (hard copy and 3.5″ data disk), and
2. output results of selected alternatives.

28-5.04 Documentation Project Check List

The Documentation Project Check List is shown as Figure 28-5A.

28-6.0 PIPE CLASSIFICATION SYSTEM

28-6.01 Introduction

INDOT has developed and implemented a Pipe Classification System which is intended to enhance the performance and longevity of pipe materials used for culverts, storm drains, underdrains and other drainage facilities. This is a comprehensive system which impacts all INDOT procedures and documents related to pipes, including the following:

1. the *Indiana Design Manual*,
2. the INDOT *Standard Specifications,* and
3. the INDOT *Standard Drawings*.

Part IV discusses the INDOT Pipe Classification System. The information is segregated as follows:

1. Section 28-6.0 discusses information which applies to all pipes regardless of type of drainage appurtence.

2. Chapter Twenty-nine has incorporated those elements of the System which apply to hydrology (e.g., choice of hydrologic method).

3. Chapter Thirty-one has incorporated those elements of the System which apply to culverts (e.g., culvert design process, cover).

4. Chapter Thirty-six has incorporated those elements of the System which apply to storm drains and underdrains (e.g., minimum velocity, inlet spacing).

28-6.02 Description

The Pipe Classification System consists of the following:

1. Type 1 Pipe. Culverts under mainline and public road approach pavement.
2. Type 2 Pipe. Storm drain pipe.
3. Type 3 Pipe. Culverts under driveways and field entrances.
4. Type 4 Pipe. Underdrains and drain title.
5. Type 5 Pipe. Broken-back and other pipe installations which require coupled pipe.

Section 715.02 of the *Standard Specifications* lists the materials that have been approved for each pipe type.

Although the Pipe Classification System serves as the foundation of drainage structure design, other structure types are available for use as appropriate. One such category is referred to as Specialty Structures. A Specialty Structure will be used when the design process indicates that the materials included in the Pipe Classification System do not provide an adequate hydraulic structure. Specialty Structures include the following:

1. precast reinforced concrete box sections,
2. precast reinforced concrete three-sided culverts, and
3. structural plate arches.

Specific Application Structures are also not included in the Pipe Classification System but are available for use as appropriate. These structures include the following:

1. concrete culvert extensions,
2. pipe extensions,
3. slotted drain pipe or slotted vane drain pipe, and
4. end bent drain pipe.

28-6.03 Design Process

The drainage structure design process, excluding Specific Application Structures, begins based on the assumption that the Pipe Classification System includes materials that can provide a structure that meets all design requirements. Specialty Structures must not be considered until it has been demonstrated that the appropriate System pipe type cannot provide a hydraulically adequate structure.

Specific design requirements relative to culvert (Chapter Thirty-one) and storm drain (Chapter Thirty-six) sizing are detailed elsewhere in Part IV, but there are general concepts that apply to the implementation of the Pipe Classification System. These concepts are discussed below.

1. Interior Designation. Sizing of pipe type structures is based on a parameter known as interior designation. An interior designation (smooth or corrugated) has been assigned to each Type 1, 2, 3 and 5 Pipe material (Type 4 pipe sizes are usually not determined by hydraulic calculations). Individual materials must not be considered during the sizing process for pipe type structures. More information on the interior designation parameter is contained in Chapter Thirty-one.

2. Materials. Each pipe type in the Pipe Classification System includes a list of approved materials. However, except for Type 4 Pipe, the approval is general in nature. For example, individual mainline culvert sites may possess features that render the site unsuitable for some approved Type 1 Pipe materials. Therefore, it is necessary to perform a Structure Site Analysis for each Type 1, 2, 3 or 5 Pipe structure. Features to be considered during the analysis include cover and service life criteria (i.e., service life duration, abrasive/non-abrasive site designation, and structure pH). See Section 28-6.04 for additional information on the Structure Site Analysis.

28-6.04 Structure Site Analysis

A Structure Site Analysis is required for each Type 1, 2, 3 or 5 Pipe structure. Unless noted otherwise, the analysis is not required for Type 4 Pipe structures, Specialty Structures or Specific Application Structures. The scope of the analysis is discussed in the following sections.

28-6.04(01) Cover

Cover is measured from the pipe crown to the bottom of the proposed pavement. The depth of aggregate base under HMA pavement or subbase under concrete pavement is included in the

cover dimension. The allowable cover depths vary by pipe material, but a few general rules apply. For circular pipes, the minimum cover should always be $\geq$ 300 mm, and the maximum cover should always be $\leq$ 30.5 m. For deformed pipes with a corrugated interior designation, the minimum cover should be $\geq$ 450 mm. If these guidelines cannot be met, it is necessary to consider other structure types before continuing with the Structure Site Analysis.

In addition to pipe type structures, the cover depth must be determined for structures using precast reinforced concrete box section(s).

28-6.04(02) Pipe Service Life Duration

This factor indicates the desired length of service for the drainage structure. The duration is based on the functional classification of the mainline roadway. If the mainline roadway has a freeway or arterial functional classification, the required service life duration for all Type 1, 2, 3 and 5 Pipe structures in the contract is 75 years. The required service life for all such structures in contracts with a collector or local mainline roadway functional classification is 50 years.

28-6.04(03) Abrasive or Non-Abrasive Site Designation

A site is considered abrasive if it is probable that runoff will transmit material which could damage the pipe. The following sites are always considered abrasive.

1. all mainline culvert sites, and
2. sites where public road approach or driveway culverts are installed in natural channels.

In general, storm drain sites and public road approach or driveway culvert sites on constructed side ditch lines are considered non-abrasive. However, the designer must use judgment to confirm that abrasive elements are not likely to impact these sites. If the designer concludes that a storm drain or a side ditch culvert site could have abrasive materials transported by runoff, an abrasive site designation must be assigned to all affected structures.

28-6.04(04) Structure pH

In some areas, acidic runoff has contributed to service life problems with pipe structures. To mitigate these problems, the designer must determine a pH value for each Type 1, 2, 3 or 5 pipe structure. In some instances, pH data will be provided in the Project Scoping and/or

Geotechnical Reports. This data should include stream pH test results for the following existing structures within the project area:

1. all mainline culverts,
2. all public road approach and driveway culverts in natural channels,
3. all storm drain system outlet pipes, and
4. the most downstream culvert on each constructed ditch line.

The designer will use the following guidelines to establish proposed structure pH values.

1. Culverts. Assign the data provided for each existing mainline culvert to the corresponding proposed pipe structure. Likewise, assign the data associated with each existing public road approach or driveway culvert located in natural channels to the corresponding proposed structure. All proposed driveway and public road approach culverts installed on constructed ditch lines shall be assigned the report pH value for the most downstream culvert on the corresponding existing ditch line.

2. Storm Drains. If a proposed storm drain system will replace an existing system, assign the pH value obtained at the existing drain outlet pipe to every pipe structure in the proposed system. If the proposed storm drain system is replacing an existing open drainage system, apply the pH value collected at the most downstream existing side ditch culvert to every structure in the proposed system.

The final structure pH is the lower(est) of the following values.

1. Preliminary Field Check Plans pH Value. This value is obtained from one of the following sources:

    a. Engineer's Report.

    b. pH Testing. If pH data is not available from a Scoping Report, INDOT designers and consultant designers that have a Design Agreement with testing provisions are required to perform pH testing of water samples taken at the structure. The scope of the testing required is discussed later in this section and illustrated by the flowcharts contained in the following figures.

    28-6B Structure pH Determination Procedure (Proposed Mainline Culverts & Other Culverts in Natural Channels) (Project in Area Where Map pH = 7.0)
    28-6C Structure pH Determination Procedure (Proposed Storm Drain Structures) (Project in Area Where Map pH = 7.0)
    28-6D Structure pH Determination Procedure (Proposed Side Ditch Culverts) (Project in Area Where Map pH = 7.0)

28-6E Structure pH Determination Procedure (Proposed Mainline Culverts & Other Culverts in Natural Channels) (Project in Area Where Map pH < 7.0)
28-6F Structure pH Determination Procedure (Proposed Storm Drain Structures) (Project in Area Where Map pH < 7.0)
28-6G Structure pH Determination Procedure (Proposed Side Ditch Culverts) (Project in Area Where Map pH < 7.0)

c. pH Map. If a Scoping Report does not provide structure pH data and pH testing is not appropriate, Figure 28-6A, the pH Map, is used to determine the Preliminary Field Check pH value.

2. Final Check Prints pH Value. This value is obtained from one of the following sources.

a. Geotechnical Report.

b. pH Testing. If no structure pH value is available from a Geotechnical Report and testing is appropriate (see Item 1b. above), then pH testing of a water sample taken from the corresponding existing structure site is required.

c. pH Map. Use of the pH map is only appropriate when no structure pH value is available from the two above sources.

3. Tracings pH Value. If the pH values from No. 1 and No. 2 for a structure are not within 0.5 of each other, a third value must be obtained for comparison. The third value is obtained from one of these two sources.

a. pH Testing. If pH testing is appropriate for the project, testing of water samples at the corresponding existing structure is required.

b. pH Map. If pH testing is not appropriate for the project, the pH map is the appropriate source for the third pH value.

Before pH testing is performed on a project, the project location must be determined on Figure 28-6A, the pH Map. If the project is located in a county with a posted 7.0 pH value, the testing scope is as follows:

1. Identify Structures Requiring Testing. The following structures to be considered for testing are as follows:

a. all mainline culverts,
b. all public road approach or driveway culverts located in natural channels,

c. outlet pipes of storm drain systems, and
d. the most downstream culvert on a constructed ditch line.

2. Structure Inspection. The testing process begins by inspecting the structures noted above. If a structure shows no signs of corrosion, then no pH testing is required. If the existing structure shows signs of corrosion, then a sample of water at the structure must be obtained and the pH of the sample must be determined.

If the project is located in a county with a pH map value < 7.0, the structure inspection step noted in Item 2 does not apply. All structures identified in Item 1 require obtaining a water sample for pH determination.

The following rules apply to the determination of structure pH values, regardless of the source of the data.

1. Maximum Structure pH Value. The pH value for a structure cannot exceed the pH map value for the project location. If the pH value obtained from a report on pH testing is greater than the pH map value for the project location, the obtained value is ignored and the map value is used for the structure.

2. Precision of pH Value. The pH value is expressed to the nearest 0.5. If a report or pH testing yields a value that is more precise, the structure pH is rounded to the next lower 0.5.

3. Lack of Sample Availability. If pH testing is required, but no sample is available at a structure site, the structure pH value will equal the value for the nearest adjacent structure. If water samples are not available at any of the appropriate structures within a project area, the pH map value is used for all structures.

4. Storm Drain Structure pH Determination. The structure pH assigned to the outlet pipe of a storm drain system is assigned to all structures in the proposed system.

5. Side Ditch Culvert Structure pH Determination. The structure pH assigned to the most downstream pipe in a segment of side ditch is assigned to all culverts installed in that ditch line segment.

28-6.05 Pipe Material Selection Process

The data collected during the Structure Site Analysis is used to determine which pipe materials are acceptable for installation at individual structure sites. A computer program has been developed to perform the required material selection for Type 1, 2, 3 and 5 Pipe structures.

The input required for the Pipe Material Selection Software includes the following:

1. Required Pipe Type;
2. Required Pipe Interior Designation, if applicable (refer to Chapter Thirty-one);
3. Pipe Size;
4. Cover;
5. Required Service Life Duration;
6. Abrasive/Non-Abrasive Site Designation; and
7. Structure pH.

The software analyzes the input and lists all pipe materials that are acceptable for installation at individual structure sites.

For material selection, each corrugated metal pipe protective coating or invert treatment is considered to define a unique material. For example, an acceptable materials list with zinc-coated corrugated steel pipe and zinc-coated corrugated steel pipe with bituminous paved invert is considered to contain two materials.

The following rules apply to the performance of the Pipe Material Selection Process.

1. Software Indicates No Acceptable Materials for Structure. When this occurs, the cause is often incorrect input data entry. If a review of the input reveals that there are no errors, the designer must contact the INDOT Standards Section for additional instructions.

2. Software Indicates Only One Acceptable Material for Structure. By definition, a pipe-type designation indicates that a Contractor may select from a list of materials that have been determined to be acceptable for an individual structure. If the list contains only one acceptable material, the pipe-type designation is meaningless. When this occurs, the structure cannot refer to a pipe type. See Section 28-6.08 for more information on contract document requirements for these structures.

3. Software Indicates Two or More Materials are Acceptable for Structure. By definition, a pipe-type designation remains appropriate for these structures.

4. Pipe Extension Structures. Pipe extensions require the selection of a specific material. If possible, the selected material should match the existing pipe material. However, the material thickness/coating combination or material strength classification must meet all

cover and service life criteria requirements. By definition, a pipe extension structure is any structure that involves attaching new pipe to existing pipe.

5. Selection of Corrugated Metal Pipe Optimum Corrugation Profile. It is possible that the Pipe Material Selection Software could indicate that more than one corrugation profile/material thickness combination is acceptable for a structure. It is then necessary to determine the optimum corrugation profile. The rules related to determining the optimum corrugation profile are as follows:

   a. Select the Profile with the Minimum Thickness. If the acceptable corrugation profiles require different material thicknesses, select the profile with the minimum thickness.

   b. Select the Smallest Profile. If all acceptable corrugation profiles require the same material thickness, select the smallest profile. By definition, a 68 mm x 13 mm corrugation profile is considered smaller than a 75 mm x 25 mm profile.

28-6.06 Drain Tile Structures

If it is known that the proposed construction will require the removal of existing field tile, the drainage will be perpetuated in the following manner.

1. Tile Replacement Within Temporary R/W. Type 4 Pipe is used to perpetuate the drainage. The pipe size will match the existing tile and must be perforated in accordance with the *Standard Specifications*.

2. Tile Outlets in Ditch Prior to Crossing Mainline Pavement. Type 4 Pipe (non-perforated) and a 3.0-m long segment of Drain Tile Terminal Section is required between the R/W line and the proposed outlet. If necessary, a concrete collar (detailed in the plans) is used to connect to the existing pipe at the R/W line, and a rodent screen is required at the terminal section outlet. Revetment riprap or other gradation as required to conform with the clear zone criteria (see Chapter Forty-nine) is required between the tile outlet and the ditch flow line to prevent erosion.

3. Tile Outlets in Ditch After Crossing Mainline Pavement. Type 1 Pipe is required between the R/W line and the proposed outlet. The concrete collar, rodent screen and riprap requirements noted in Item #2 apply to the Type 1 Pipe installation. The acceptable Type 1 Pipe materials must conform to all cover and service life criteria. The site is assumed to be non-abrasive and the map pH can be assigned to the structure.

4. Tile Outlets in Storm Drain System. Type 2 Pipe is required between the R/W line and the outlet location. The concrete collar requirements are identical to those described above. The Type 2 Pipe acceptable materials must conform to all cover and service life criteria. The site is assumed to be non-abrasive, and the structure pH must match the value for the storm drain structure that serves as the tile outlet.

5. Tile is Perpetuated Across R/W. Type 1 Pipe is required from R/W line to R/W line. Concrete collar requirements are identical to those described above. The acceptable Type 1 Pipe materials must conform to all cover and service life criteria. The site is assumed to be non-abrasive, and the pH map value for the project location is assigned to the structure.

28-6.07 Decision Flowcharts

The following figures provide the user with decision flowcharts for the INDOT Pipe Classification System.

1. Figure 28-6A, pH Map,

2. Figure 28-6B, Structure pH Determination Procedure (Proposed Mainline Culverts & Other Culverts in Natural Channels) (Project in Area Where Map pH = 7.0),

3. Figure 28-6C, Structure pH Determination Procedure (Proposed Storm Drain Structures) (Project in Area Where Map pH = 7.0),

4. Figure 28-6D, Structure pH Determination Procedure (Proposed Side Ditch Culverts) (Project in Area Where Map pH = 7.0),

5. Figure 28-6E, Structure pH Determination Procedure (Proposed Mainline Culverts & Other Culverts in Natural Channels) (Project in Area Where Map pH < 7.0),

6. Figure 28-6F, Structure pH Determination Procedure (Proposed Storm Drain Structures) (Project in Area Where Map pH < 7.0),

7. Figure 28-6G, Structure pH Determination Procedure (Proposed Side Ditch Culverts) (Project in Area Where Map pH < 7.0).

28-6.08 Contract Documents

Part II and the Separate Document on Typical Plan Sheets discuss the various INDOT requirements on the preparation of contract documents for a project (e.g., plan preparation, quantity estimates, cost estimates). Section 28-6.06 provides additional information on contract document preparation for requirements for drainage structures.

28-6.08(01) Plan Content

The following is necessary to incorporate information on drainage structures into the set of plans.

1. Typical Cross Section Sheet. This Sheet is the appropriate location for details related to the installation of longitudinal underdrains.

2. Plan and Profile Sheet. This Sheet is the appropriate location for drainage structure callouts. Sample callouts are as follows:

    a. 20.0 m 900 mm Pipe and 2 Pipe End Sections Required.

    b. 20.0 m 900 mm Smooth Pipe and 2 Pipe End Sections or 1050 mm Corrugated Pipe and 2 Concrete Anchors Required.

    c. 20.0 m 900 mm Smooth Pipe and 2 Pipe End Sections Required.

    d. Manhole Type C-4 and 100.0 m 450 mm Pipe Required.

    e. 20.0 m 300 mm Slotted Drain Pipe Required.

    f. 75.0 m 2400 mm x 1200 mm Precast Reinforced Concrete Box Sections Required. Skew 30° Right.

    Culvert structure and storm drain outlet structure lengths will be expressed to the nearest 0.5 m. Other storm drain structure lengths are expressed to the nearest 0.1 m with the measurement taken from outside face to outside face of the adjacent manholes, inlets, catch basins or similar structures.

    Specialty Structures and Specific Application Structures must be identified in the structure callout. Structures that refer to a pipe type or require a specific pipe material are identified in the structure callout as “Pipe.”

3. Detail Sheet. All drainage structure related features that are not included in the *Standard Drawings* must be detailed on this Sheet. Some commonly used features that require

such detailing include concrete collars required to join existing and proposed pipe and Specialty Structure backfill requirements.

4 Structure Data Sheet. The following rules apply to the preparation of this Sheet:

a. Specialty Structures and Specific Application Structures are identified in the "Description" column to the right of the "Pipe Type" column. This identification for pipe extensio structures is simply "Pipe Extension." Concrete culvert extensions using precast reinforced concrete box sections identify the extension material by entering "Precast Reinforced Concrete Box Section Culvert Extensions" in the "Description" column. No entry is made in the "Pipe Type" column.

b. For structures that refer to a pipe type, identify it in the "Pipe Type" column and the word "Pipe" is entered in the "Description" column.

c. Structures that require a specific pipe material do not have an entry placed in the "Pipe Type" column. The word "Pipe" is entered in the "Description" column.

d. Pipe type structures that require different sizes based on the interior designation require separate rows of input data for each interior designation.

5. Pipe Material Sheet. This Sheet is used to list the acceptable pipe materials for all pipe type structures (excluding Type 4 Pipe), specific pipe material structures, and pipe extension structures.

6. Underdrain Table. This Sheet is used to summarize the complete underdrain design for the project. For more details regarding underdrain design procedures, see Chapter Fifty-two.

28-6.08(02) Backfill Material

The standard backfill material for all pipe structures is B borrow for structure backfill. However, the INDOT *Standard Specifications* permit the use of flowable mortar in all cases and require its use in other cases involving thermoplastic pipe.

28-6.08(03) Special Provisions

The *Standard Specifications* include no specifications regarding sanitary sewers or potable water distribution systems. If sanitary sewer or potable water distribution system construction is included in the contract, a special provision must be developed to cover all aspects of the work.

28-6.08(04) Pay Items

Sample drainage system related pay items are listed below.

1. Pipe, Type 1, Circular, 900 mm. This is the typical pay item format for pipe type structures. Its use indicates that at least two materials are acceptable for the structure. Also, for Type 1, 3 and 5 Pipe, the lack of an interior designation in the pay item indicates that the materials acceptable for installation include some with a smooth interior designation and others with a corrugated interior designation.

2. Pipe, Type 2, Circular, 300 mm. This pay item illustrates the typical format for a storm drain pipe structure. Because all Type 2 Pipe materials have a smooth interior designation, the word "Smooth" is not included in the pay item.

3. Pipe, Type 1, Circular, 900 mm Smooth or 1050 mm Corrugated. This pay item indicates that there are at least two materials acceptable for the structure. At least one has a smooth interior designation and at least one has a corrugated interior designation. The hydraulic design indicates that different sized smooth and corrugated interior pipe sizes are required.

4. Pipe Type 3, Deformed, Min. Area = 0.15 m^2 Corrugated. This pay item indicates that there are at least two materials acceptable for installation and all have a corrugated interior designation.

5. Pipe, RCP, Class II, $D_{0.3}$ = 50, 900 mm. This pay item indicates that reinforced concrete pipe meeting the above strength requirements is the only acceptable material for a new pipe structure. Reinforced concrete pipe pay items must include the required strength classification and the D-load rating.

6. Pipe Extension, ZC CSP w/BPI, 2.77 mm, 450 mm. This pay item indicates that a zinc-coated corrugated steel pipe with a bituminous paved invert and a material thickness of 2.77 mm is the only acceptable material for a structure that involves placing new pipe on the end(s) of an existing pipe. Corrugated metal pipe pay items must include the protective coating, any required invert treatment, and the required material thickness.

7. Culvert, Precast Reinforced Concrete Three-Sided, 6000 mm x 3000 mm. This pay item illustrates the typical format for Specialty Structure and Specific Application Structure pay items. The Specialty Structure or Specific Application Structure must be identified in the pay item.

8. Pipe End Section, 900 mm. This pay item illustrates the typical format for objects placed on the end(s) of a structure that has only one specified pipe size.

9. Concrete Anchor 1050 mm or 1200 mm. This pay item illustrates the typical format where a structure has different sized smooth interior and corrugated interior alternatives. In this situation, a concrete anchor is required regardless of the pipe size that is actually installed.

10. Pipe End Section, 900 mm or Concrete Anchor, 1050 mm. This pay item illustrates the format where a structure with different sized smooth interior and corrugated interior alternatives require different objects placed on the pipe end(s). In this case, pipe end sections are required if the 900-mm structure alternative is installed and concrete anchors are required if the 1050-mm structure alternative is installed.

The following rules pertain to miscellaneous drainage structure related pay items and corresponding quantity calculations.

1. Backfill Material. Unless specifically directed to use flowable mortar backfill, "B borrow for Structure Backfill" will be the appropriate pay item for the backfill of pipe type structures, specific material pipe structures, and pipe extension structures. The "Flowable Mortar" pay item is only used if a designer has been specifically directed to use flowable mortar backfill for these structures. Regardless of the backfill material, the quantities will be calculated in accordance with the details shown on the appropriate INDOT *Standard Drawings*.

2. Backfill for Pipe Type Structures with Different Sized Smooth and Corrugated Interior Alternatives. It is necessary for the designer to calculate backfill quantities for both structure alternatives for entry on the Structure Data Sheet. However, the smooth interior alternative quantity will be used for the structure when calculating the quantity for the contract.

28-6.09 English-to-Metric Conversion Information

Figures 28-6H through 28-6S provide conversion information related to drainage structures. These figures are provided to give designers the ability to convert results from English design

software, nomographs, etc., to the appropriate corresponding metric dimensions. The figure designations with their titles are listed below.

28-6H	Circular Smooth Pipe (Conversion From English Design Pipe Size to Metric Pay Item Pipe Size)
28-6 I	Circular Corrugated Pipe (Conversion From English Design Pipe Size to Metric Pay Item Pipe Size)
28-6J	Circular Corrugated Pipe (Structural Plate) (Conversion From English Design Pipe Size to Metric Pay Item Pipe Size)
28-6K	Deformed Corrugated Pipe (Conversion From English Design Pipe Size to Metric Pay Item Pipe Size)
28-6L	Deformed Corrugated Pipe (Structural Plate) (Conversion From English Design to Metric Pay Item Pipe Size)
28-6M	Deformed Smooth Pipe (Conversion from English to Metric Pay Item Pipe Size)
28-6N	Precast Reinforced Concrete Box Sections (Conversion from English Design to Metric Pay Item Pipe Size)
28-6 O	Precast Reinforced Concrete Three-Sided Culvert (Conversion from English Design to Metric Pay Item Pipe Size)
28-6P	Non-Reinforced Concrete Pipe (Class 3 Wall Thickness)
28-6Q	Reinforced Concrete Pipe Wall Thickness
28-6R	Precast Reinforced Concrete Box Section (Wall Thickness)
28-6S	Reinforced Concrete Horizontal Elliptical Pipe (Wall Thickness)